Analysis of the Impact of Biomass Burning on Tropospheric O_3 Using Assimilated TES Observations and Complementary Satellite Data

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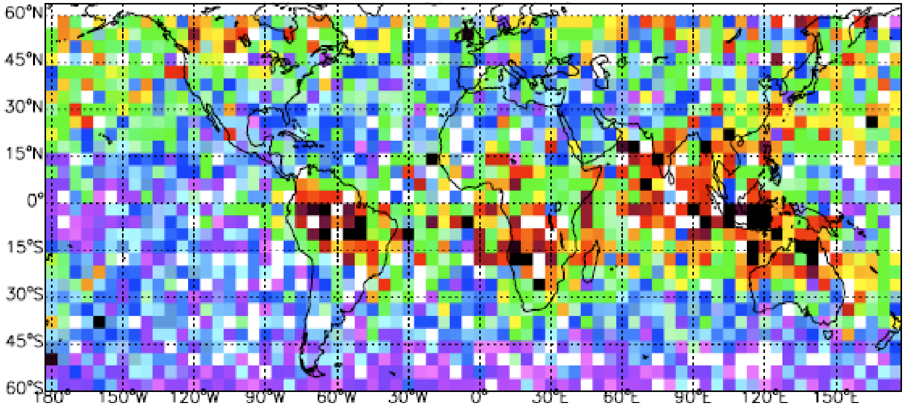
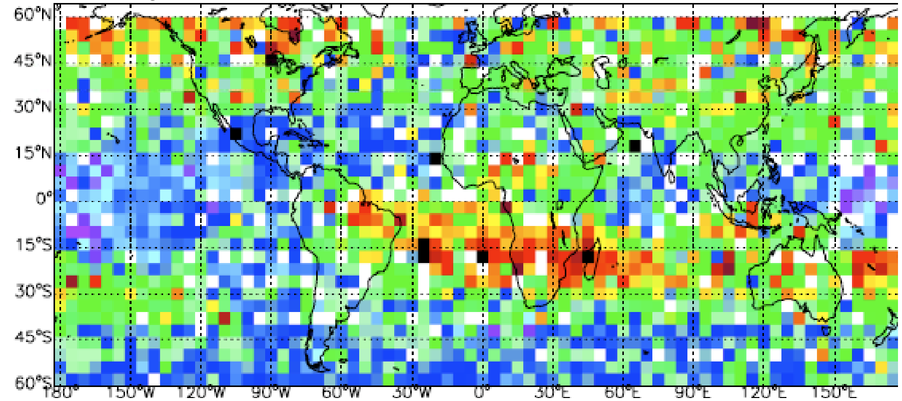
Analysis of the Impact of Biomass Burning on CO and O_3

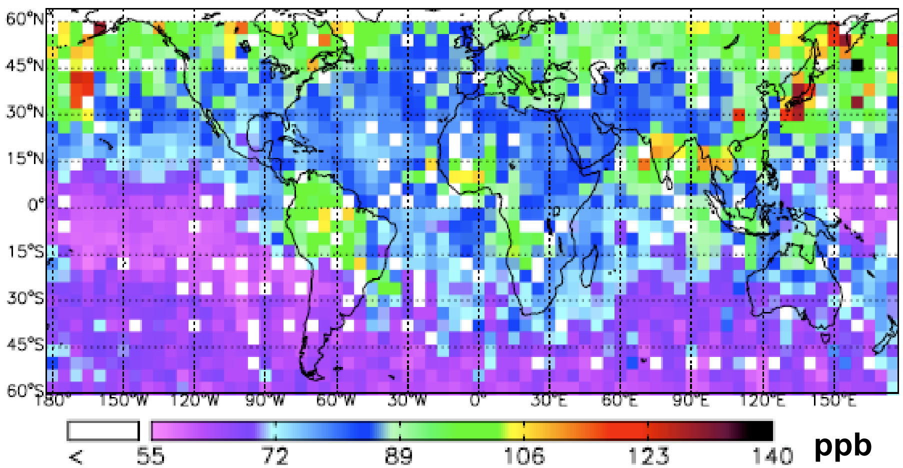
TES CO, 421 mb: Nov 4-17, 2004



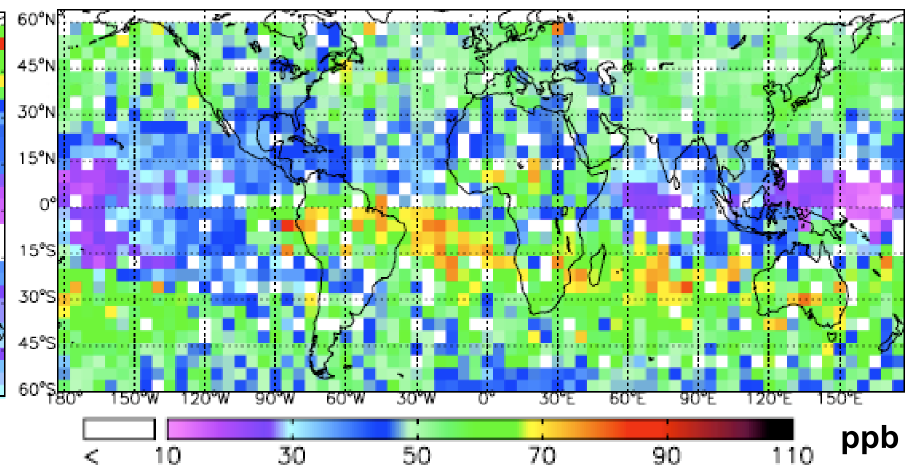
TES O_3, 421 mb: Nov 5-17, 2004



GEOS-Chem CO 421 mb: Nov 4-17, 2004



GEOS-Chem O_3, 421 mb: Nov 4-17, 2004



Climatological emission inventory in the model underestimates the biomass burning

Objective: Assess whether the TES data have sufficient information to correct the underestimate in the model in a chemical data assimilation framework

Chemical Data Assimilation Methodology

Sub-optimal Kalman filter

$$\hat{\mathbf{x}}_k^a = \mathbf{x}_k^f + \mathbf{K}_k[\mathbf{y}^{\mathrm{obs}} - \mathbf{H}_k\mathbf{x}_k^f]$$

Kalman Gain Matrix: $\mathbf{K}_k = \mathbf{P}_k^f\mathbf{H}_k^{\mathrm{T}}(\mathbf{H}_k\mathbf{P}_k^f\mathbf{H}_k^{\mathrm{T}} + \mathbf{R}_k)^{-1}$

Analysis Error Cov. Matrix: $\mathbf{P}_k^a = (\mathbf{I} - \mathbf{K}_k\mathbf{H}_k)\mathbf{P}_k^f$

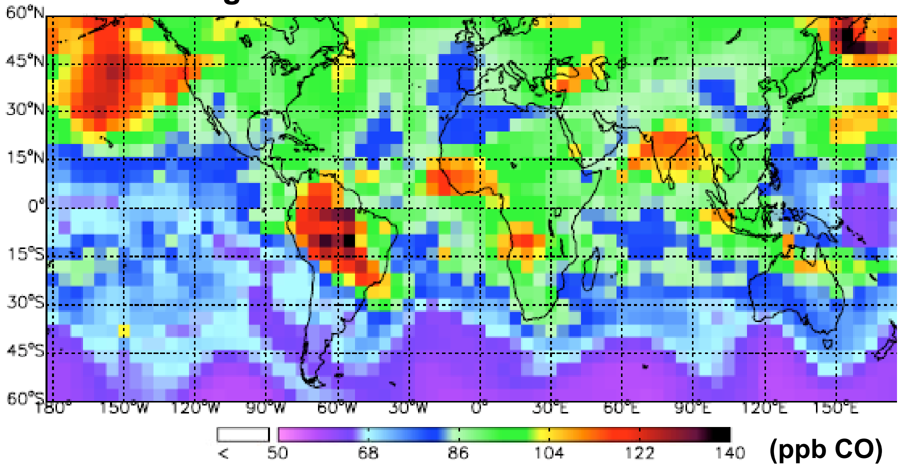
(analysis error variance transported as a passive tracer)

Model and Data Streams

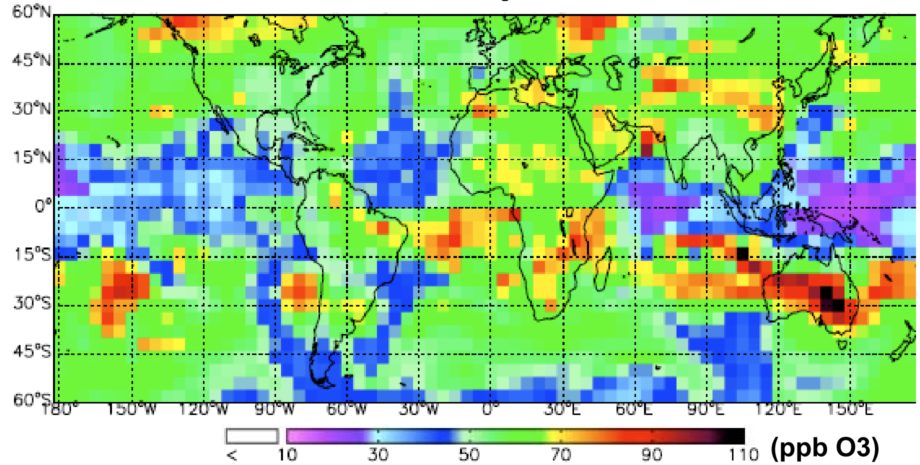
- **GEOS-Chem model with full nonlinear tropospheric chemistry (4° x 5° resolution)**
- **CO profile retrievals from TES for Nov. 4-17 2004**
- **O_3 profile retrievals from TES for Nov. 4-17 2004**
- **NO_2 column retrievals from SCIAMACHY for Nov. 4-17, 2004**
- **6-hour analysis cycle**
- **Assumed forecast error of 20% for CO, 50% for O_3, and 100% for NO_2**
- **Neglected horizontal correlations in forecast and observation error covariance matrices**

Impact of Assimilation on CO and O_3

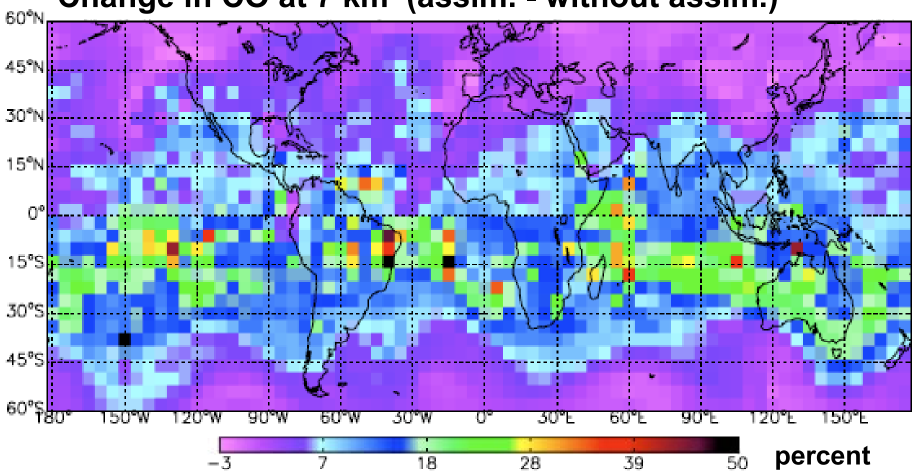
24-hr averaged assimilated CO at 7 km on Nov. 17



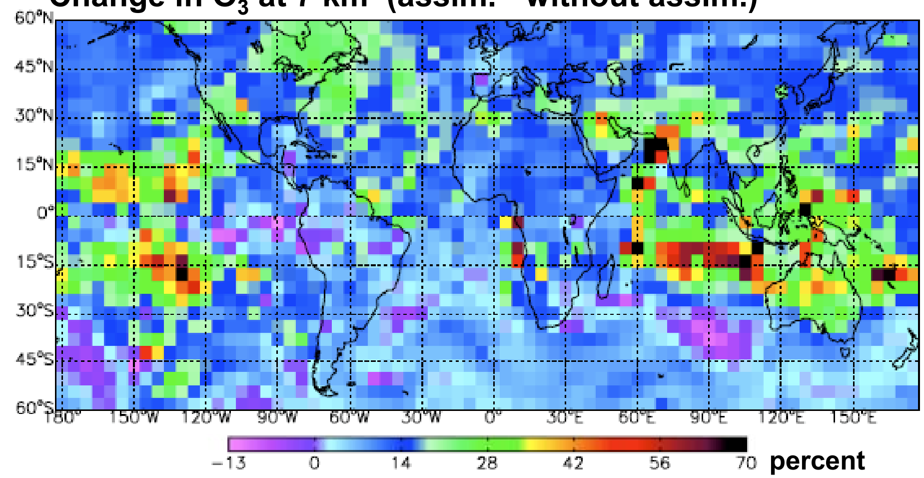
24-hr averaged assimilated O_3 at 7 km on Nov. 17



Change in CO at 7 km (assim. - without assim.)



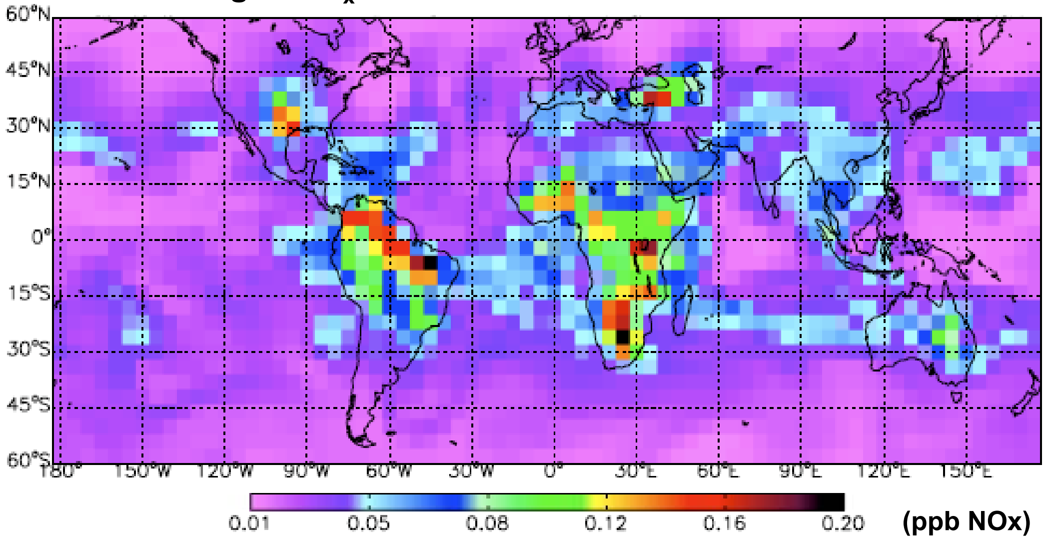
Change in O_3 at 7 km (assim. - without assim.)



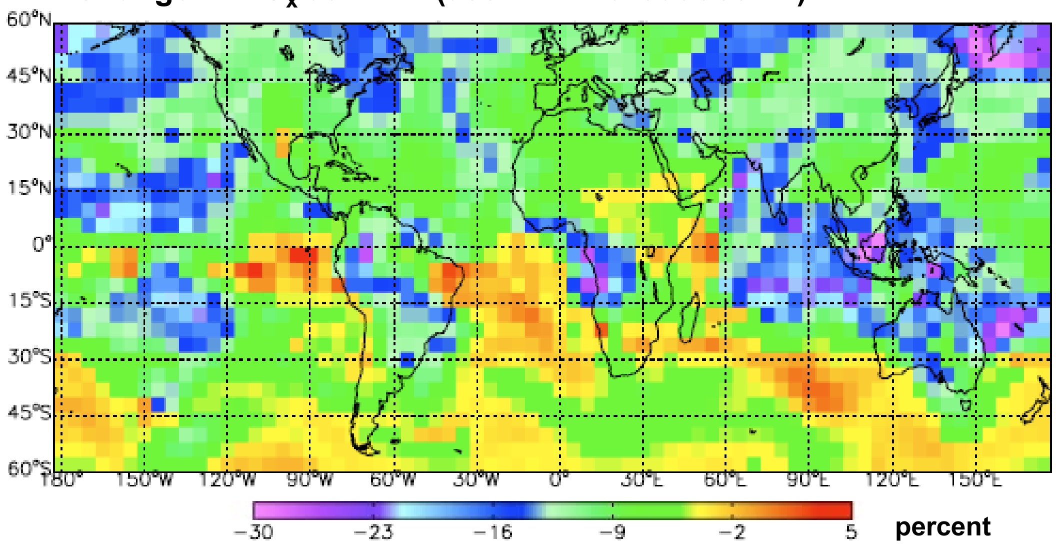
- Assimilation increases CO throughout the southern hemisphere
- Largest increases in O_3 (20-30%) are over the Indian Ocean and the Indonesian/Australian region

Influence of Assimilation of O_3 on NO_x

24-hr averaged NO_x at 7 km on Nov. 17



Change in NO_x at 7 km (assim. - without assim.)



Modelled NO_x distribution produced with the assimilation of TES CO and O_3

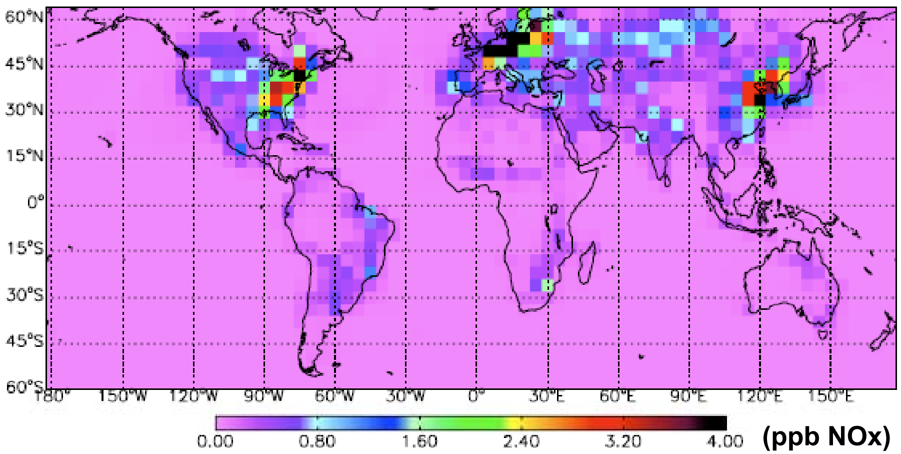
Assimilation of O_3 significantly influences the NO_x distribution, because of the chemical coupling:

large decreases in NO_x (15-30%) over the Indian Ocean and the Indonesian/Australian region, where the O_3 increase is the greatest

Suggests that changes in O_3 in the assimilation can provide constraints in the chemical processes in the model

Assimilation of SCIAMACHY NO_2

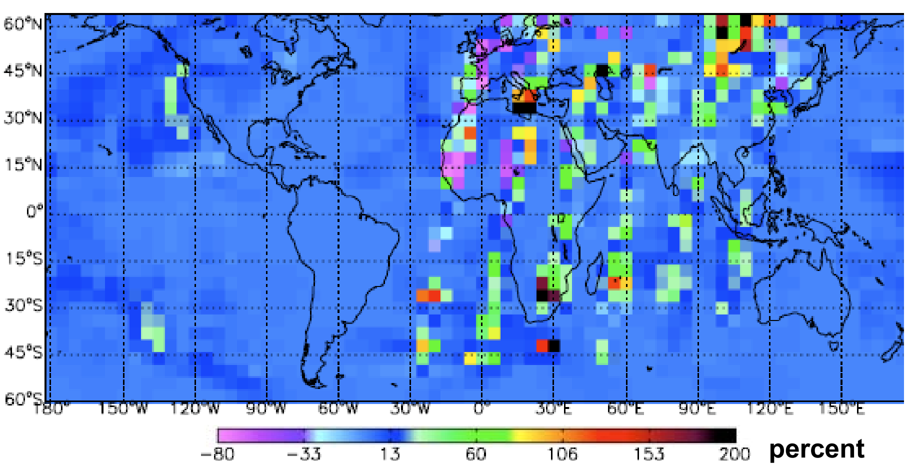
Assimilated NO_x at 1 km at 09:00 GMT on Nov. 5th



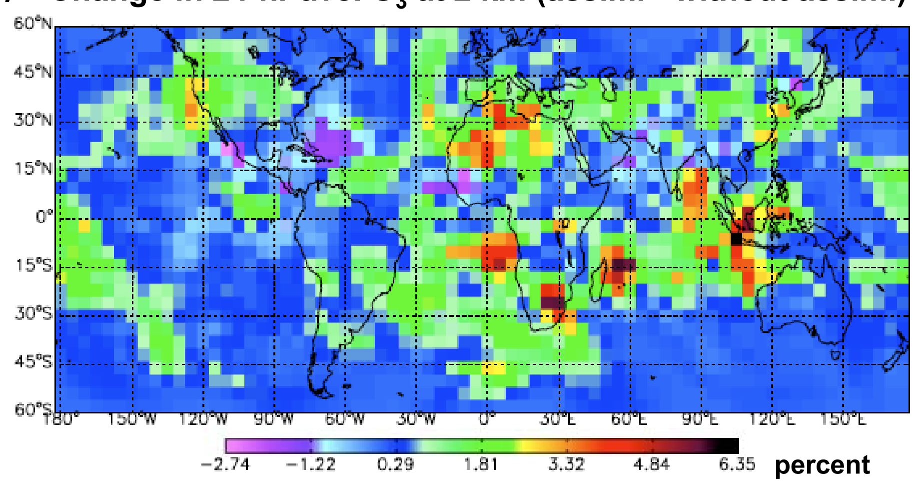
Assimilation includes only NO_2 from SCIAMACHY

- Large local changes in NO_x due to the NO_2 assimilation
- Changes in O_3 are small, due to short lifetime of NO_x

Change in NO_x at 1 km 09:00 GMT (assim. - without assim.)



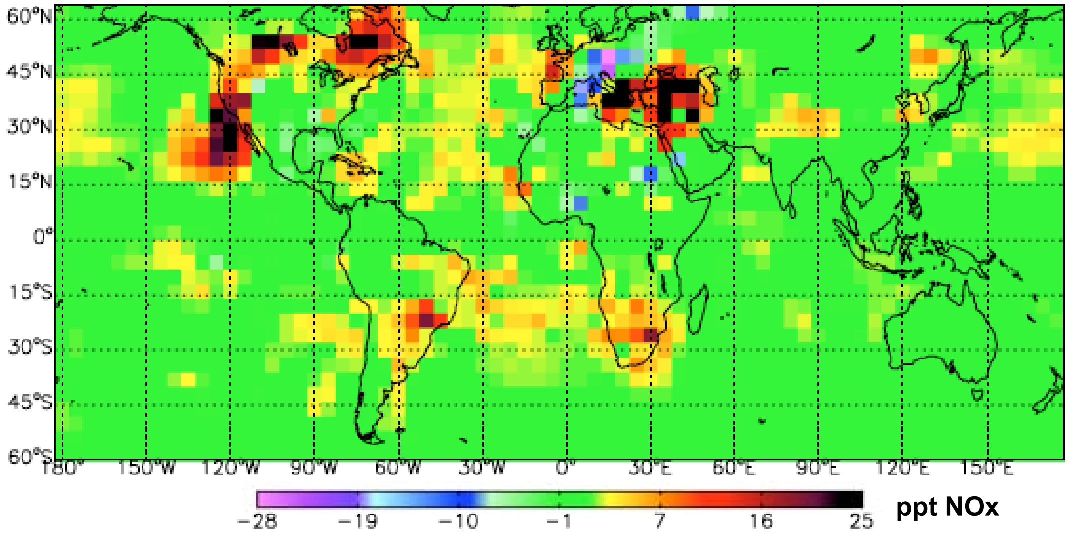
Change in 24-hr ave. O_3 at 2 km (assim. - without assim.)



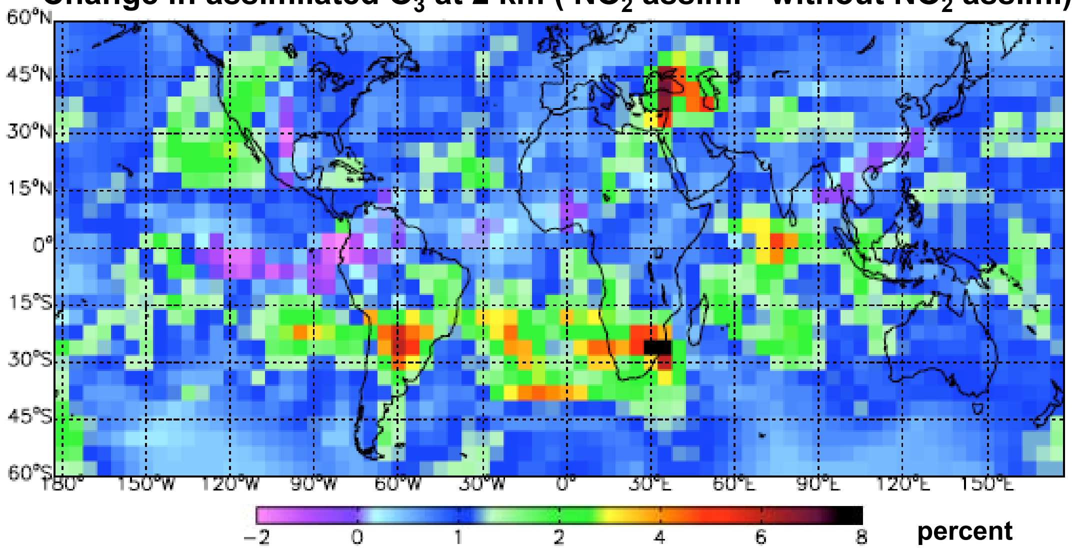
- Assimilation of NO_2 helps constrain the chemistry, but will require obs. with greater spatial and temporal coverage
- Updating the NOx emissions in the assimilation would be the most effective approach

Assimilation of O_3, CO, and NO_2

Absolute change in NO_x at 2 km on Nov. 14th



Change in assimilated O_3 at 2 km (NO_2 assim. - without NO_2 assim.)



Assimilation includes data from SCIAMACHY and TES

- In the southern hemisphere, largest changes in NO_x are typically over South America, Africa, and the Atlantic

- NO_2 assimilation produced small additional increases in O_3 (beyond increases produced by assimilation of the TES data)

- Largest NO_x-induced increases in O_3 are over South America, Africa, and the Atlantic, whereas the O_3 assimilation led to increases in O_3 mainly over the Indonesian region
  $\Rightarrow$ SCIA NO_2 is providing limited but complementary information in the assimilation

Conclusions

- **Assimilation of TES data reduced significantly the underestimate of CO and O_3 from biomass burning in the southern hemisphere in the model**
  $\Rightarrow$ TES CO and O_3 have sufficient information, when assimilated in a CTM, to dramatically improve the model simulation of CO and O_3

- **Assimilation of O_3 observations results in a repartitioning of NO_y in the model, with large changes in the abundance of NO_x, reflecting the underlying chemical processes**
  $\Rightarrow$ the assimilation of TES data, together with an adjoint of the CTM, will enable us to obtain a better understanding of the chemical processes controlling O_3

- **Assimilation of NO_2 from SCIAMACHY provides constraints on NO_x, but its effect is limited because of the short lifetime of NO_x**

  - **assimilation of observations with greater spatial and temporal coverage (such as NO_2 from OMI) would be helpful**
  - **a 4Dvar dual state-source estimation approach will provide the best constraints on the chemistry**